



Flexible TPS Development

- **Mission Simulation Testing**

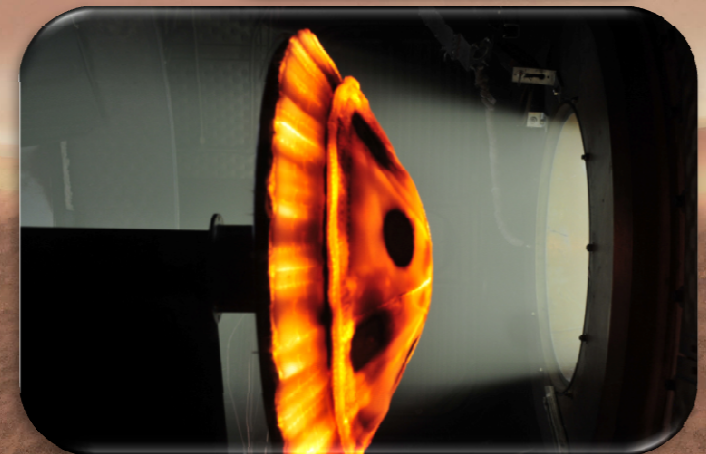
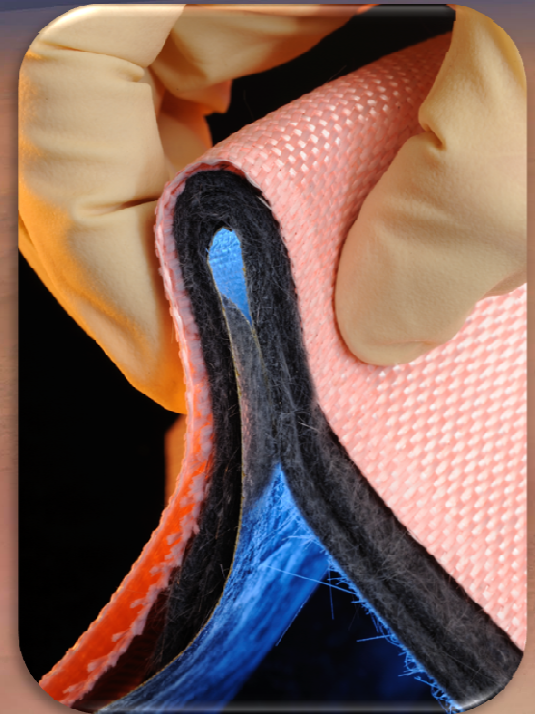
- LaRC 8-Foot High Temperature Tunnel (HTT)
- Laser Hardened Materials Exposure Lab (LHMEL)
- ARC Panel Test Facility (PTF)
- JSC Test Position 2 (TP2)
- Boeing Large Core Arc Tunnel (LCAT)

- **Materials Testing and Characterization**

- Materials Development/Characterization for All Layers (heatshield, insulator, gas barrier, structure)
- Age Testing
- Surface Catalycity

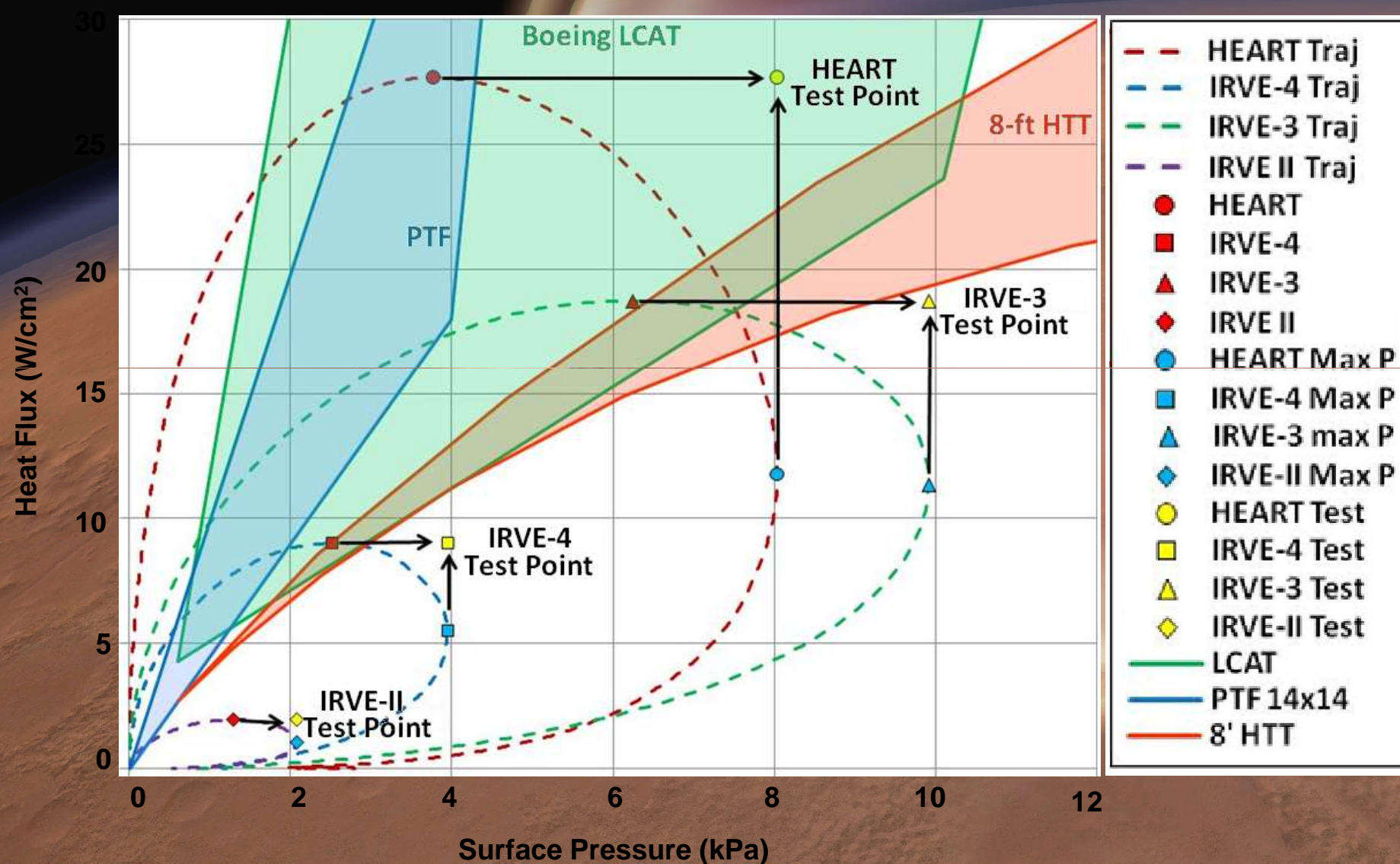
- **Physics-Based Modeling**

- Inter-layer Heat Transfer (convective and radiative) Characterization
- Analytical Model Development





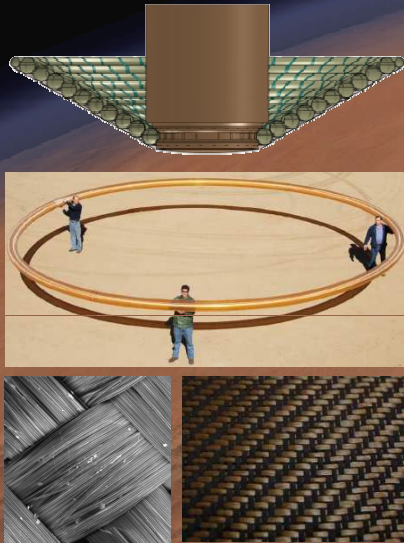
Mission Profiles/Facility Envelopes





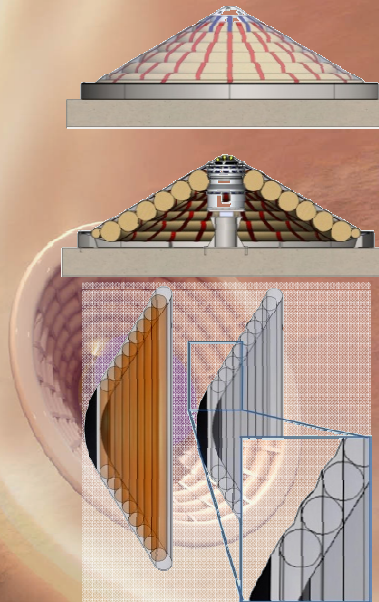
Advancement of Inflatable Structures

Large-Scale Manufacturability & Material Development



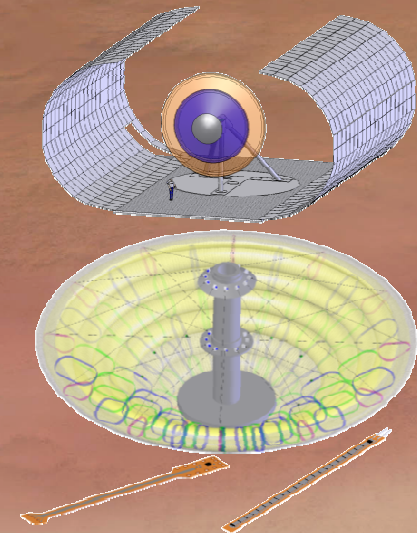
Development of large-scale manufacturing capabilities and advanced, high-temperature capable inflatable structure materials

Large-Scale Static Load Testing, Component Testing & Model Development



Ground test to demonstrate HIAD scalability and initial structural model development

Large-Scale Wind Tunnel Testing & Instrumentation Development

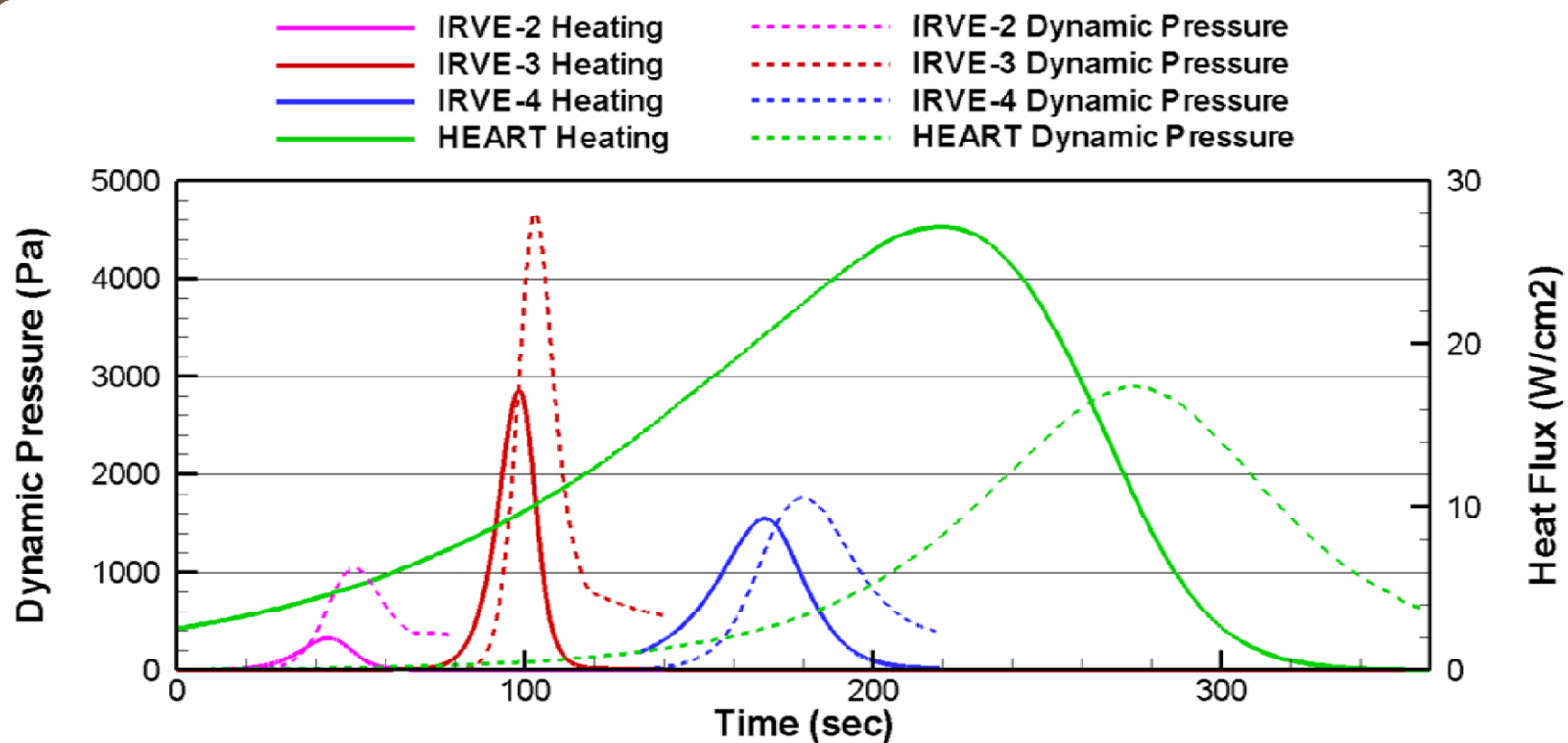


Ground test to demonstrate HIAD performance under flight-like aerodynamic loading



Progression of HIAD Development Flights

	IRVE-II	IRVE-3	IRVE-4	HEART
Peak Heating (W/cm^2)	2	15	7	27
Dynamic Pressure (kPa)	1.2	4.7	2	3
Angle of Attack (deg)	0	7	10	0
Diameter (meters)	3	3	3	8.3





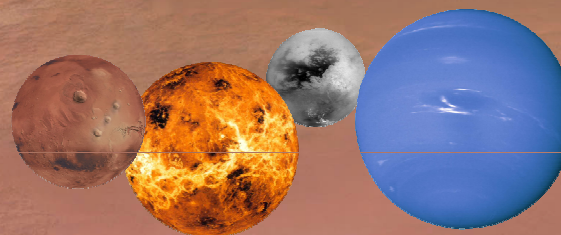
Mission Applications: Plans Forward

• Objectives

- Identify the improvements associated with HIAD integration within the concept of operations of high priority missions
 - Reduced launch costs?
 - Increased performance margins?
 - Expanded mission potential and science return?
- Provide full systems view of HIAD integration
- Conduct what-if scenarios to guide future investments.



ISS downmass, LV booster recovery, Earth return (LEO, GEO, lunar, NEO)



Sample return, robotic entry at Mars, Venus, Titan, and gas giants, human-scale entry at Mars

• Approach

- On-going trade studies
 - Release trade study results over multiple analysis cycles
 - Expand scope and fidelity with each cycle
 - Special projects
 - Perform analysis in response to ad-hoc requests



Near Term Milestones

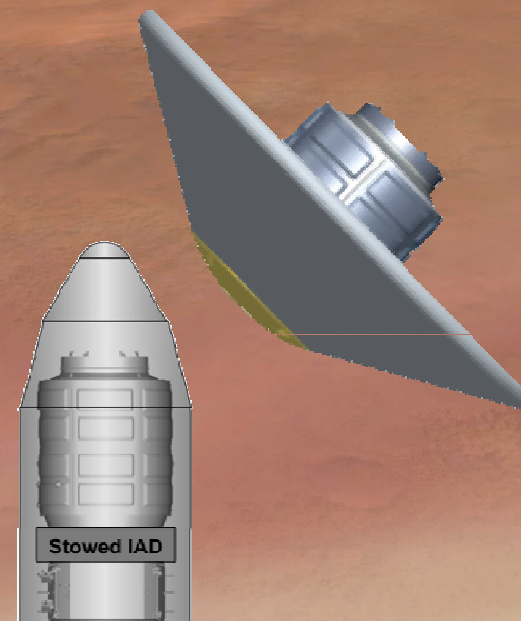
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

- **November, 2011:** LV Booster Recovery Quick Look
- **January, 2012:** Cycle 1 Trade Study (Benchmark)



HEART Reference Concept Description

- HEART integrates all aspects of the HIAD Development Project to demonstrate the performance and survivability of an integrated low ballistic coefficient entry vehicle in a relevant environment
- **HIAD Vehicle**
 - Single 7 - 9 m diameter HIAD (8.5 m nominal)
 - 55 to 65 degree sphere cone-stacked torus (55 degree nominal)
 - Entry: mass ~3300-3500 kg; Ballistic Coefficient ~45 kg/m²
 - Ballistic entry: 0 degree AoA
- **Entry Environments — Initial Limits**
 - Peak heat rate: 25 to 35 W/cm²
 - Peak dynamic pressure: 4800 Pa
- **Launch, Orbit, De-orbit**
 - Integrated with the Orbital Sciences Corp Cygnus module as part of the ISS Cargo Resupply Service
 - NASA-OSC Data Exchange SAA in Signature Loop
 - Launch on Enhanced Taurus II
 - Cygnus berths with ISS: up to 90 days
 - Cygnus performs all maneuvering
 - Entry from LEO: 7.6 km/s
 - HIAD returns Pressurized Cargo Module

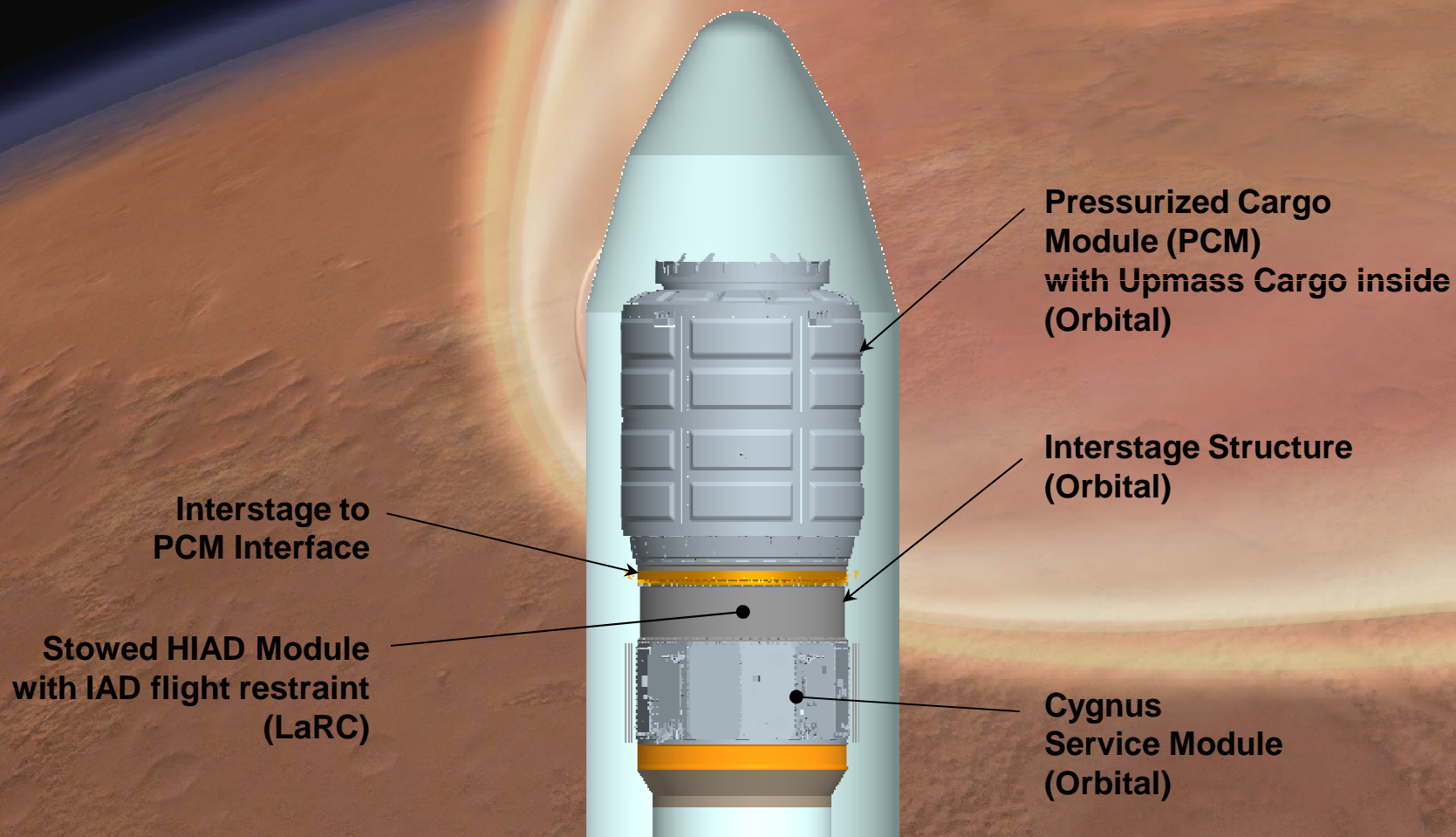




HEART Project Configurations

- **Launch Configuration: HEART and Cygnus**

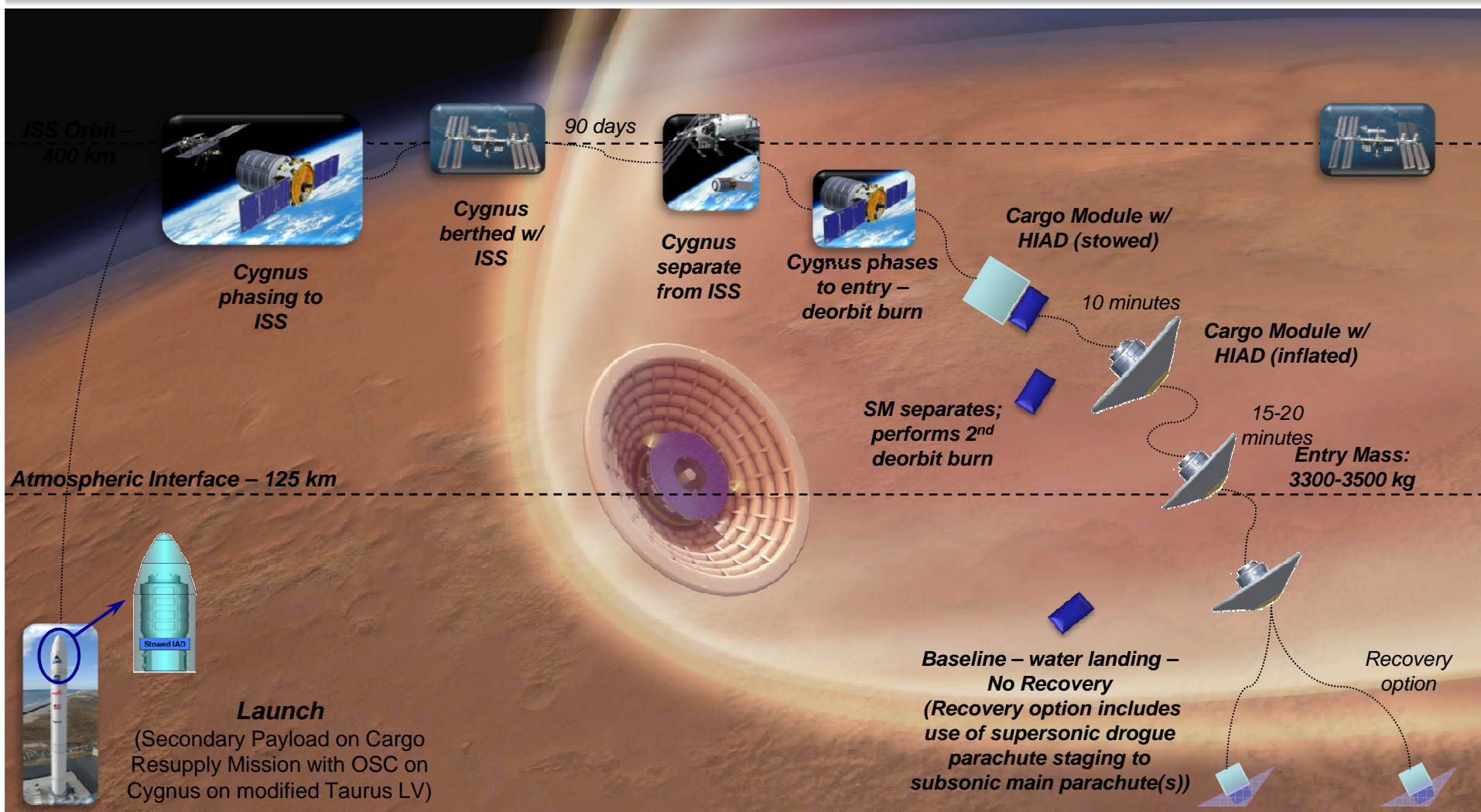
- Cygnus SM + Interstage + Stowed HIAD Module + PCM + Upmass Cargo + Flight restraint with cover





Langley Research Center

HEART Concept of Operations





NextGen Subsystems: Plans Forward

- **Alternate lift effectors**

- ✓ Two-axis movable CG
- ✓ Deployable tabs
- ✓ Fixed deployable mass
- ✓ Articulating mass boom

- **NextGen geometries**

- ✓ Pre-stressed shapes (flex under load to desired shape)
- ✓ Sharper shoulders, ellipsoidal noses, hyperboloids
- ✓ Asymmetric shapes
- ✓ Unconventional configurations

- **Test methods for large articles**

- ✓ Balloon drop of >8m at subsonic
- ✓ Balloon drop rocket-assist of >8m
- ✓ Advanced lab testing

- **G&C**

Two lift knobs (direction & magnitude)

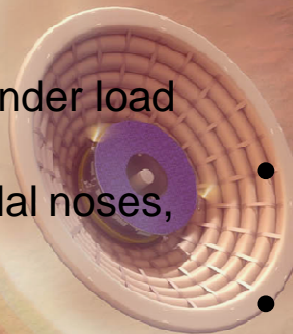
- **Aeroshell structural concepts**

- ✓ Rib and stringer
- ✓ Rigidizable
- ✓ Radial boom behind stacked torroids

- **Inflation systems**

- **Staged aeroshells**

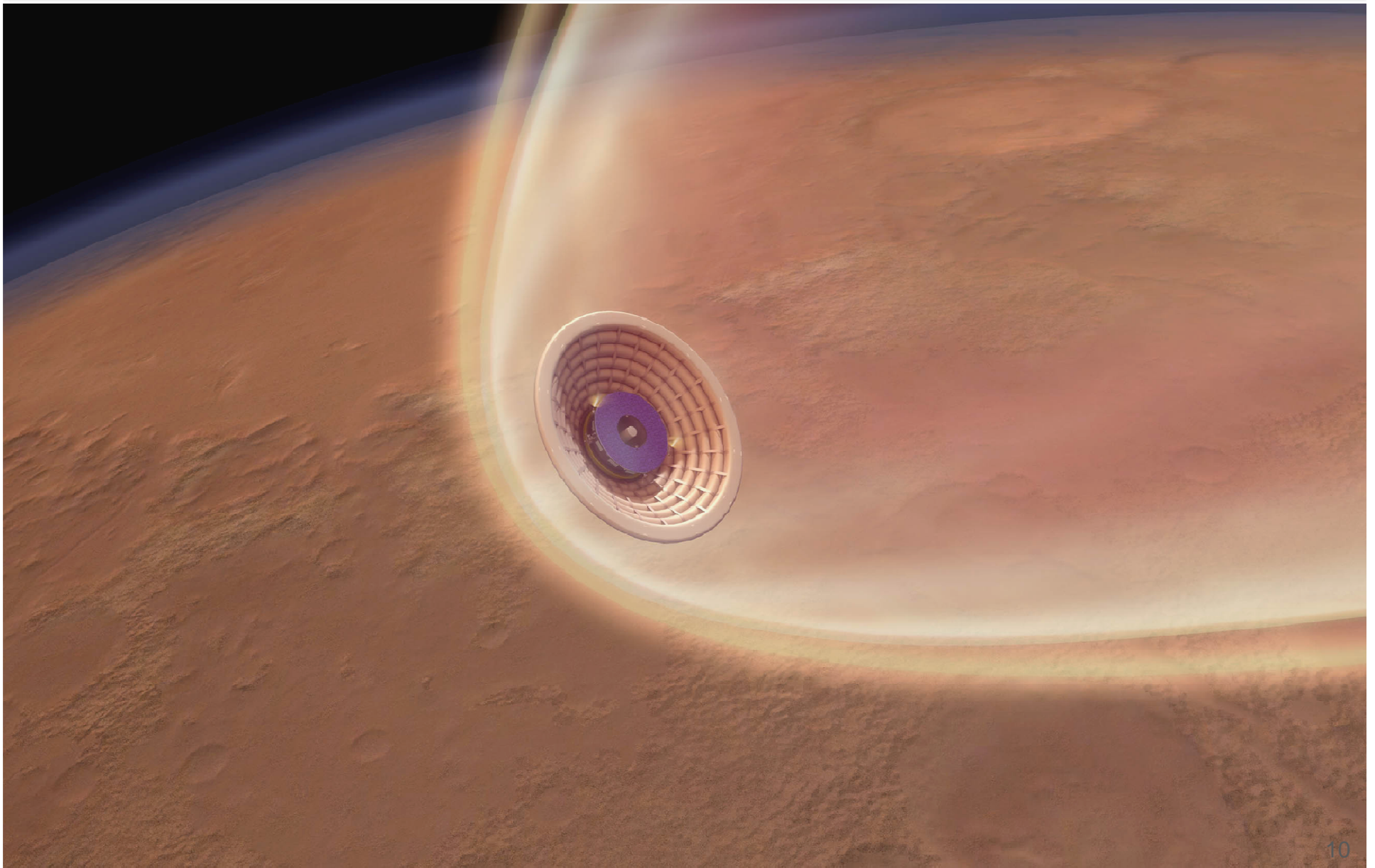
- ✓ Dual use bladders with two single-use TPS
- ✓ Drop TPS after q-pulse for supersonic
- ✓ Deploy additional area after q-pulse
- ✓ Drop outer torroids (bladder and TPS) after aerocapture before 2nd entry





Langley Research Center

Education and Public Outreach





Summary/Next Steps

- **TPS and Flexible Structures development demonstrating robotic scale mission relevant capabilities with development path to larger scales**
- **IRVE-3 flight test to demonstrate HIAD Technology in a relevant environment**
- **HEART flight test to demonstrate HIAD Technology at a relevant environment AND scale (mass and size)**
- **Team focused on achieving 2011/2012 milestones:**
 - IRVE-3: CDR (Jun), Complete System Test (Nov), Launch (Apr 2012)
 - HEART: Peer Review (May), MCR (Jul), SRR (Nov), PDR (Sep 2012)
 - Transition to Turbulence Wind Tunnel Test: LaRC M6 (Jun)
 - Flexible TPS Testing: HTT (May-Aug), Boeing LCAT (Jun)
 - Large-scale Inflatable Articles: 6-m (Sep 2011), 8.3-m (Nov 2011), NFAC Test (Jan/Feb 2012)